

Optical Reconstruction of Proton Decay Events (#2)

$$p^+ \rightarrow K^+ \bar{\nu}$$

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July 20, 2016



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Overview

- This work is building off of that presented at the last PDSim meeting

<https://indico.fnal.gov/getFile.py/access?contribId=0&resId=0&materialId=slides&confId=12389>

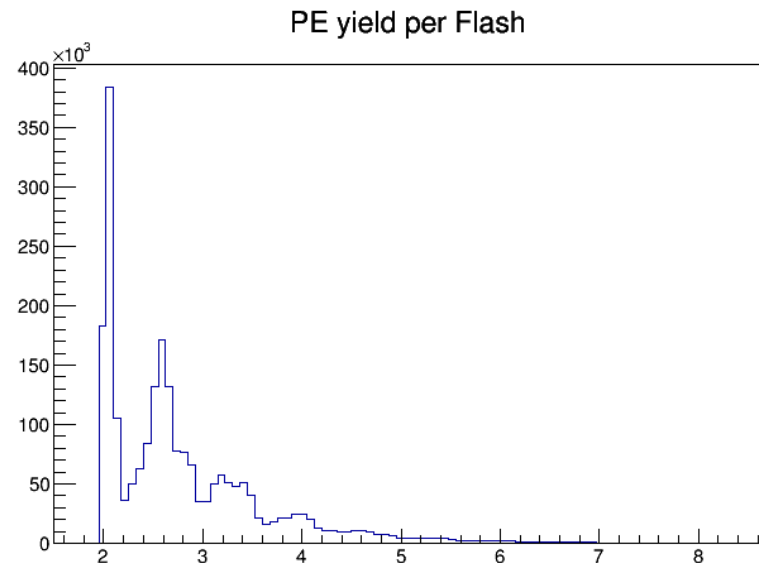
- OpHit Calibration
- Cosmogenic background
- ^{39}Ar + dark noise FlashFinding rates
- PDK flash finding efficiency

OpHit Calibration

- Noticed we were getting less PEs than we expected from PDK events
- Flash PE spectrum also indicated we weren't properly calibrated
- Tuning the calibration required introducing a “shift” parameter

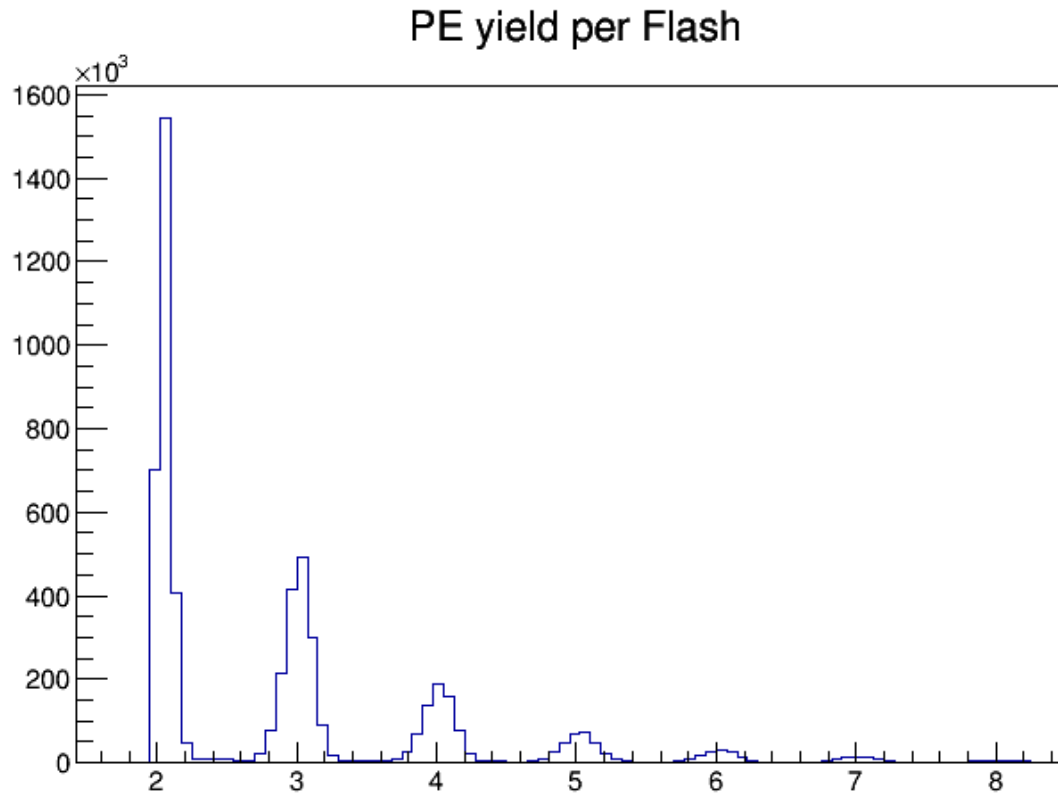
$$\text{PE} = \text{pulse.peak}/\text{SPESize} + \text{SPEShift}$$

- Cause of this is likely due to the way hit finding algorithms handle the OpDet pulse shapes
- The OpHitFinder module has been modified to accommodate such a (configurable) parameter. Infrastructure allows for channel by channel configuration, but for now the same shift is assigned to all channels.
- [Flash PE size is simple the sum of all Hit PE sizes associated with it]



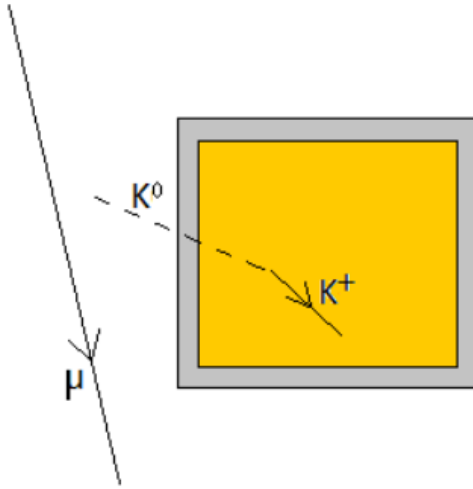
OpHit Calibration

- Tuned for DUNE configuration



- Now default config. in `dune/OpticalDetector/opticaldetectormodules_dune.fcl`

Cosmogenic Background



- Mimic PDK events near the edge of the detector
- Rate of ~ 0.05 Hz per 10kt module @ 4850 ft.
- # cosmogenic events for 400kt-year exposure:

$$0.05 \cdot (10 \cdot 365 \cdot 24 \cdot 60 \cdot 60) \cdot 4 = 6.31 \times 10^7 \text{ events/400kt-years}$$

- If light from Ar39 decay (or dark noise) is mistaken as flash for t_0 , these could be pulled further into the fiducial volume
- Let us calculate the rate at which these false-flashes occur as a function of PE threshold
- Determine the threshold that keeps the number of edge events that sneak into the fiducial volume $\lesssim 1$ event per 400kt-years
- Finally, ask: what is the PDK reconstruction efficiency at that threshold?

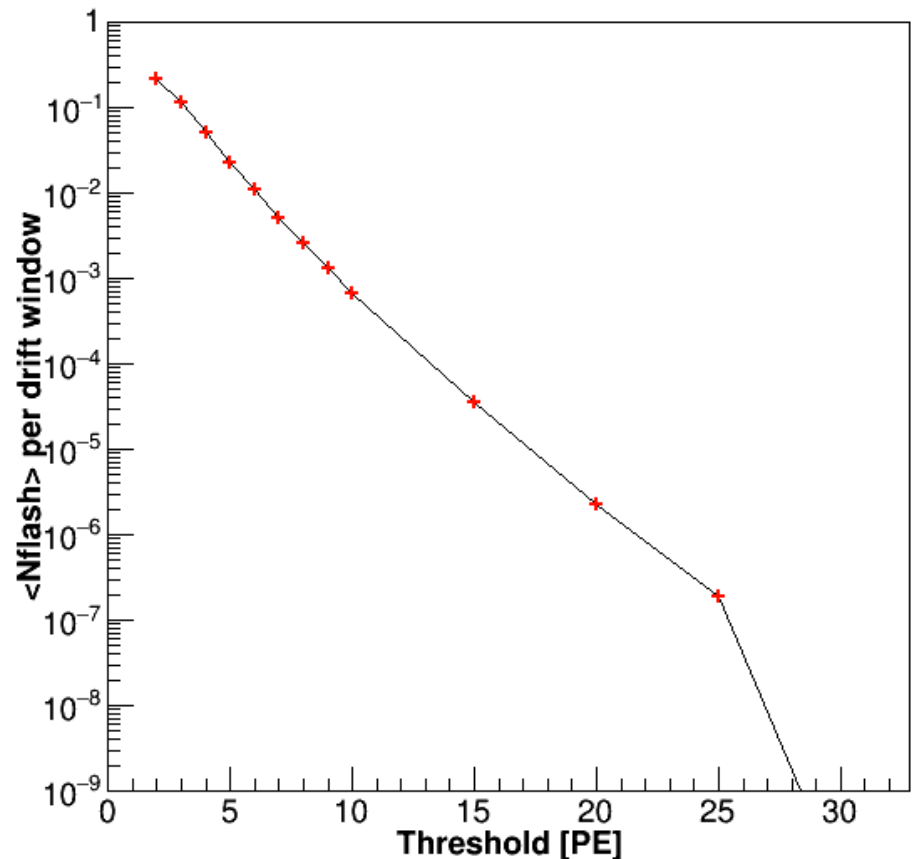
^{39}Ar + Dark Noise Flash Finding Rate

- Generated ^{39}Ar activity in 1x2x6 geometry

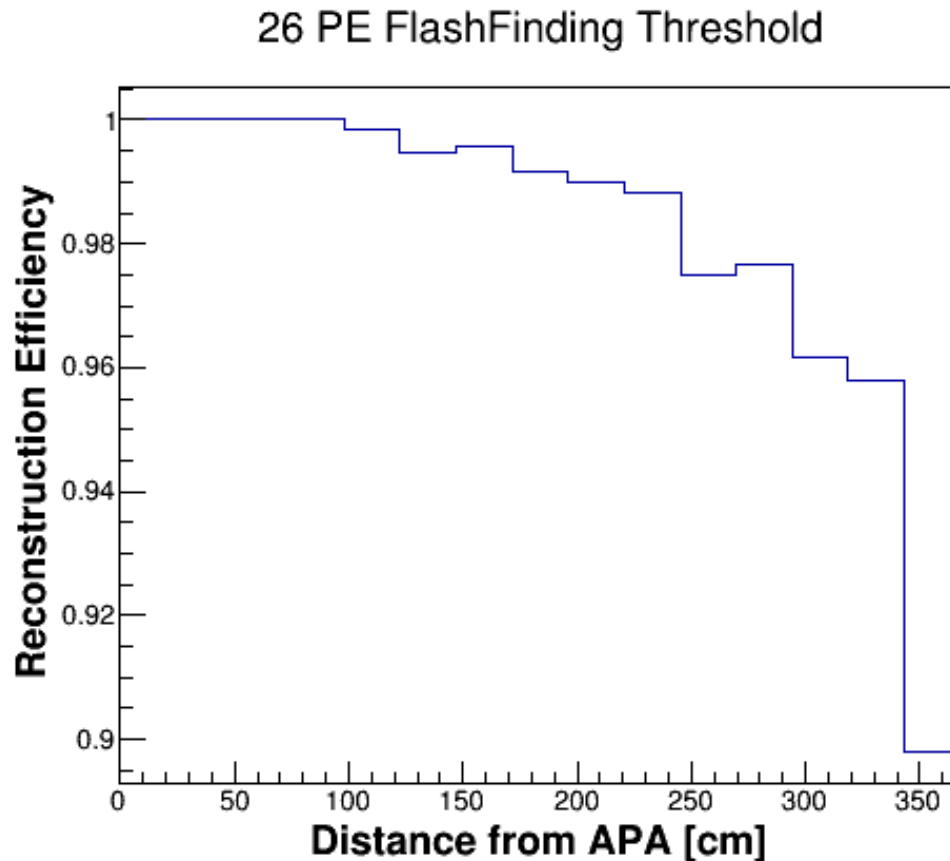
Rates shown here are for the entire volume (6 APAs)

- Ran the simulated detector response through reconstruction
- Calculated flash finding rate as a function of threshold; multiplied by 2.3ms (drift-time) to get $\langle N_{\text{flash}} \rangle$ per drift window
- Threshold of **~ 26 PEs** reduces this number to $O(10^{-7})$, keeping the # of cosmogenics with a false flash during it's drift down to $\lesssim 1$ event per 400kt-years

^{39}Ar Flash Finding



PDK FlashFinding Efficiency



- Retain ~ 99% efficiency up to 2.5m away from the APA

Room for Improvement

- (Discussion/suggestions welcome, of course)
- Of the $\sim 6 \times 10^7$ cosmogenic background events, how many can be cut from energy deposition considerations alone? Other cuts?
- What is the spatial distribution of K^+ vertex from these backgrounds?
- Using more information than just PE yield. e.g. PE distribution among paddles
- Gleb and I are getting different numbers for the false flash finding rate; we're working to understand why this is the case
- All of this analysis is in place and can be easily re-run as our estimations improve (background rate, false flash finding rate, etc.)

Summary

- Gleb, Alex, and I sorted out the OpHit calibration issue since this group met last
- With $\sim 6 \times 10^7$ cosmogenic background events per 400kt-year exposure, the flash finding threshold for t_0 should be set to $\sim 26\text{PE}$ to keep the number of these background events $\lesssim 1$
- The PDK optical reconstruction efficiency as a function of vertex distance from APA was calculated at this threshold (see slide 7). $\sim 99\%$ efficiency up to 2.5m from APA

Backup

(Calibrated) PE yield for proton decay events:

